SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

September 1985
NSRP 0226

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1985 Ship Production Symposium Volume II Paper No. 2: Evaluation of the Usability and Benefits of Twist Wire GMAW and FCAW Narrow Gap Welding

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 1985**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **The National Shipbuilding Research Program 1985 Ship Production Symposium Volume II Paper No. 2: Evaluation of the Usability and Benefits of Twist Wire GMAW and FCAW Narrow Gap Welding**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230-Design Integration Tools Building 192 Room 128 9500 MacArthur Bldg Bethesda, MD 20817-5700**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**36**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

DISCLAIMER

PUGET SOUND NAVAL SHIPYARD
Welding Engineering Division
Bremerton, Washington

Interim Report

EVALUATION OF THE USEABILITY AND BENEFITS OF TWIST WIRE GMAW & FCAW NARROW GAP WELDING 1984-1985

Prepared by

Derek H. Mortvedt
Code 138.2

Presented By

Frank B. Gatto
Head - Piping, Machinery and Pressure

ABSTRACT

Puget Sound Naval Shipyard is evaluating and developing the twisted wire narrow gap joints and reduced bevel weld joints for the shipbuilding industry. Test and evaluation work is being accomplished with twisted solid wire and twisted flux cored arc weld on carbon steel, low alloy steels (ASTM-302B) and quenched and temper steels (HY-80). Weld joint design tolerances, welding parameters tracking systems and weld joint irregularities have been evaluated with both twisted FCAW and solid welding electrodes. All test welds have been accomplished on two and three inch thick base metals. The following elements of the electrode quality were found to be critical for depositing sound metal: uniformity of the twist; tightness of the twist; smoothness of the wire; amounts of residual stress; prevention of looping; and the amount of helix.

INTRODUCTION

Puget Sound Naval Shipyard is evaluating twist wire narrow gap welding for applications in the shipbuilding industry. This evaluation is being accomplished for the Ship Productivity Panel Number Seven of the National Ship Building Research Program. The work has included the evaluation of both twist solid electrode and twist flux cored electrode. At the present time there is no routine, satisfactory welding technique in use in the United States for narrow gap welding of 1" to 3" thick marine steels. As compared to what could be achieved with twist wire narrow gap welding, the conventional welding processes in use today require large amounts of flame cutting for joint preparation, longer arc times, more filler metal and result in greater weld distortion. Currently heavy fabricated metal for ship hulls, decks, inserts, foundations, etc. requires large bevel angles for equipment access and electrode manipulation to obtain high quality welds. The twist wire welding process appears to provide an excellent alternative to expensive and time consuming conventional welding processes. The twist wire welding process gives good side wall fusion in narrow gap weld joints by the inherent weaving or rotating arc. Also, the necessary equipment for twist wire welding is not complicated.

Although the study is not yet complete, there are some basic known requirements that must be complied with for successful narrow gap welding. These include the following:

1) Quality control of wire twisting is very important. Details such as twist angle, looping, helix, residual torsion stress, serrations and tightness of twists must be monitored.
2) Weld joints that are too narrow will lead to solidification cracking and weld joints that are too wide will cause lack of fusion.

Both large diameter solid wire (2mm) and large diameter flux cored wire (3/32") will produce high quality welds in material up to 3 inches thick. Flux cored arc welding appears to have some advantage over solid wire in that it is less parameter sensitive, welds wider gaps, wets more easily, and is more easily shielded. However, slag must be removed from each weld pass.

WELD DEFECTS AND CAUSES

To evaluate the useability of the twist wire welding process it is first important to understand the causes of weld defects which are unique to one pass per layer narrow gap welding. As expected with the narrow gap joint configuration, a major problem is lack of sidewall fusion. The twist wire process elimates lack of fusion by using magnetic arc deflections and arc rotation to direct the arc force more toward the joint sidewalls. Figure 1 schematically shows how the arc is alternately generated from two solid wires of the conventional twist wire process and the resulting intermittent arc rotation. Arc stabilizers in flux cored twist wire allows an arc to be generated from both wires at all times resulting in continuous arc rotation and a dramatically lower depth-to-width ratio D/W.

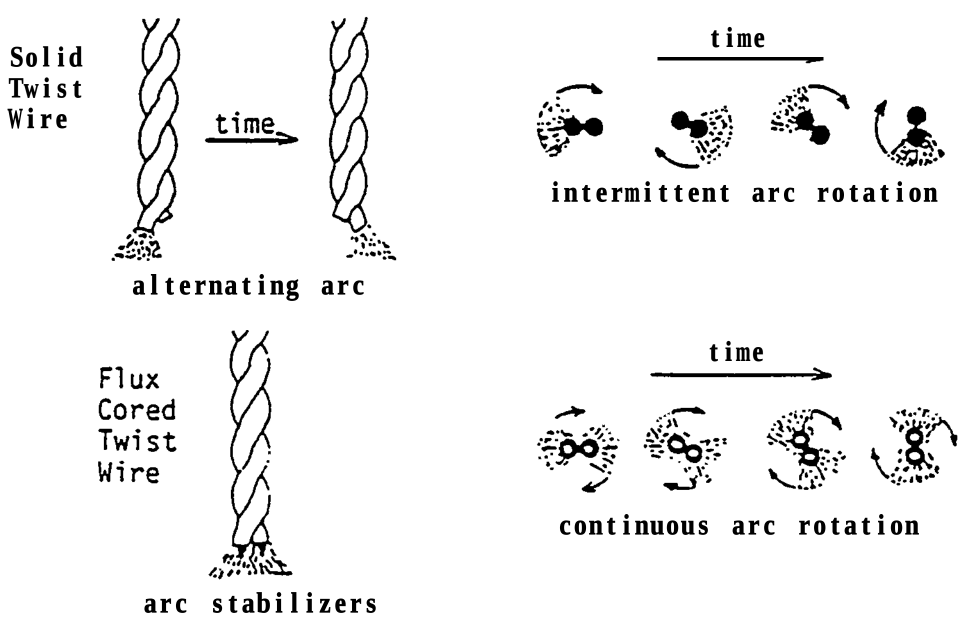
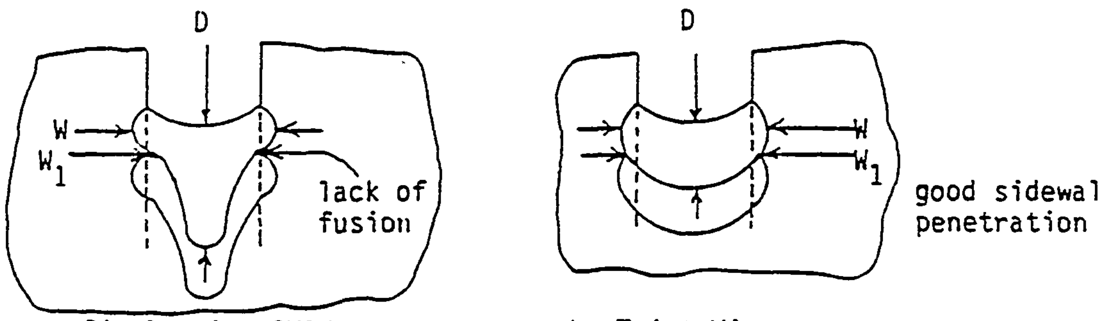


Figure 1. Arc deflections

The weld cross sectional bead shape is a very important factor to consider in eliminating sidewall lack of fusion. Figure 2 shows how the uniform bead shape eliminates lack of fusion. The desired bead shape of Figure 2b, as achieved by the twist wire welding process, has a deeper sidewall penetration throughout the weld cross section and a more uniform penetration depthwise than the bead shape of Figure 2a for single wire GMAW narrow gap welding. Even if the bead shape of Figure 2a has a greater penetration in the location W, the bead shape of Figure 2b is more desirable since it eliminates lack of fusion by increasing the sidewall penetration in the critical location W_1.



a. Single Wire GMAW

b. Twist Wire

Figure 2. Bead shape

A concave bead surface is also necessary to eliminate lack of fusion at the weld joint interface of the subsequent weld layer. Once the proper cross-sectional bead shape of Figure 2b is obtained, developing the flat bead surface of Figure 3b by increasing the gap width becomes the factor which 1 limits how wide the gap width G can be. The fiat bead surface of Figure 3b will cause lack of sidewall fusion at the bottom of the next weld bead.

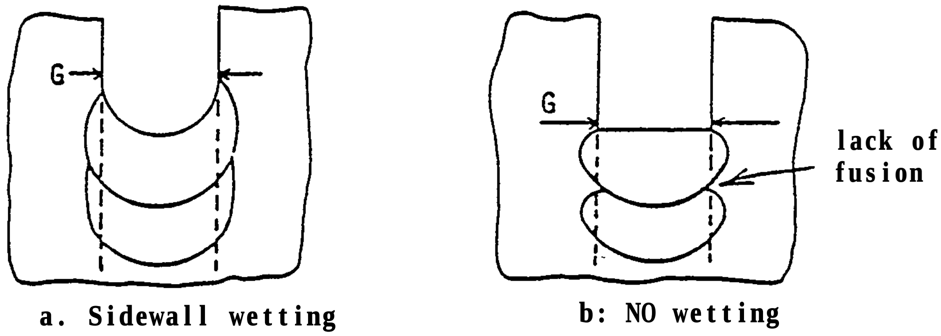


Figure 3. Bead surface

Figure 4 shows the relationship between solidification cracking and the depth to width ratio D/W of mild steel weld beads deposited under the high restraint conditions of narrow gap welds in thick plate.

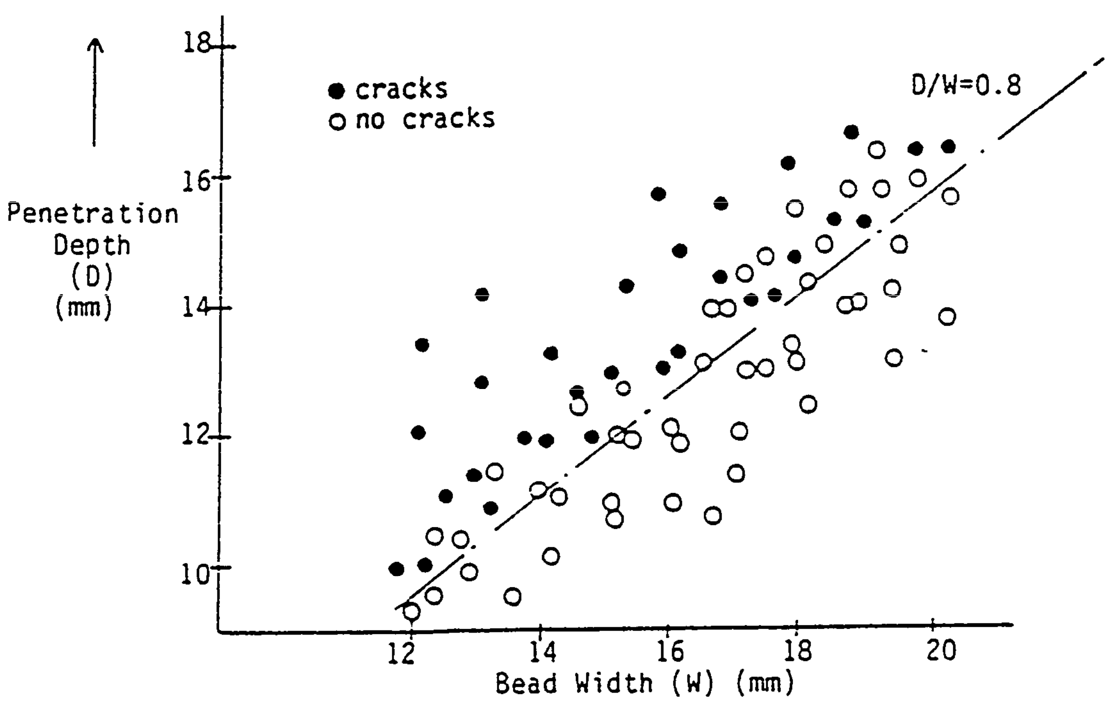


Figure 4* Conditions causing solidification cracking

Figure 4 shows that when D/W is greater than 0.8 there is a high chance of. solidification cracking. Experience has shown that when the base material

* ref. 2

or filler metal is manganese molybdenum or in general has a higher carbon equivalent than mild steel solidification cracking may occur at a lower D/W ratio. On the other hand, when twist MIL-100S-1 electrode (Mn,Ni,Mo) is used or when a plate with less restraint is welded the D/W ratio can be higher without cracking. For the sake of analysis, 0.8 was used as the maximum acceptable D/W ratio with the understanding that this value may need to be adjusted for the specific material type and weld restraint conditions.

The dendritic grain growth and segregation pattern versus the gap width is shown in Figure 5. Obviously, the D/W ratio becomes higher as the gap width G reaches the narrow end of the acceptable gap width range.
D/W = 0.8 is therefore the criteria that is use to determine the minimum gap width that can be welded without centerline cracking.

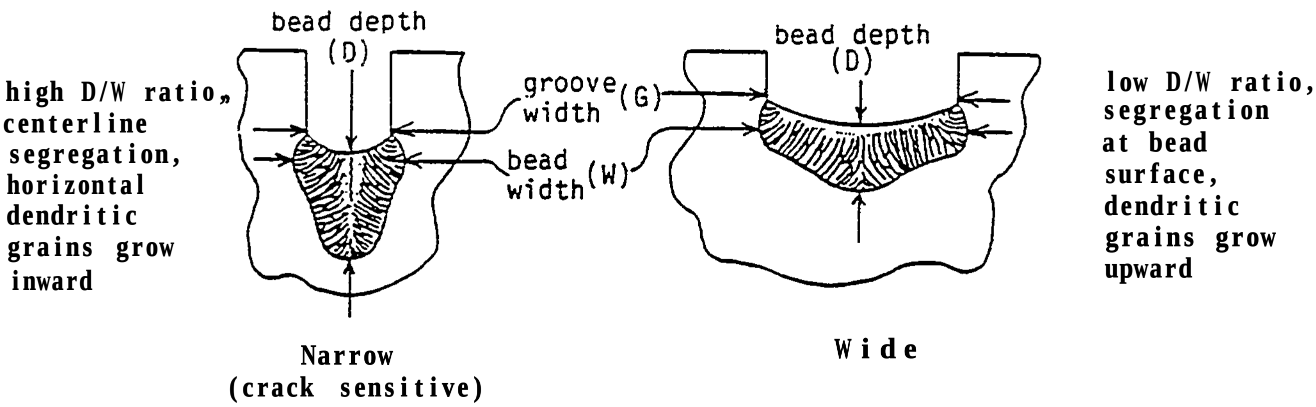


Figure 5. Depth/width ratio versus groove width

Testing has shown that the arc rotation mechanism described in Figure 1 works best at low current density for solid wire. If the amperage is raised too high, the two wires appear to produce a single steady arc and the weld cross section begins to take the shape of conventional GMAW. Figure 6 shows the penetrating spike that occurs when the arc becomes columnated and stiff at higher amperage. This increases the D/W ratio and thus the weld becomes more

crack sensitive. The bead *cross* sections outlined in Figure 6 are approximately to scale and were obtained with two twisted l/16" dia. (2 x L/16") solid electrodes and a gap width of 5/8". Although the 'maximum sidewall penetration W and the downward penetration D are increased with increasing amperage, the critical penetration W_I changes very little. The D/W ratio is drastically reduced at lower amperages, reducing the chance of solidification cracking. The lower amperage limit is reached when the arc becomes unstable. An unstable arc causes spatter which collects in the shielding gas hardware and blocks shielding gas flow. Excessive spatter will also collect on the *groove* walls and cause an undesireable bead surface as shown in Figure 3b.

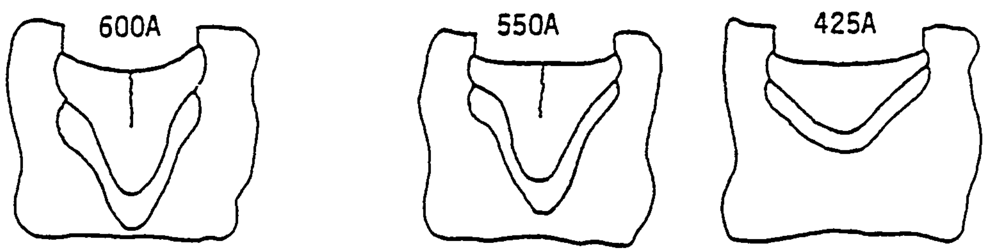


Figure 6. Depth/width ratio versus amperage.

Solidification cracking (D/W>0.8) can also occur when the travel speed is too fast. A slow travel speed increases the sidewall penetrations W and W_I much more than the increase in bead depth D. At faster travel speeds the sidewall penetration W decreases causing a higher D/W ratio and producing cracks at the narrow end of the gap range. At the same time a fast travel speed lowers sidewall penetration at W_I 'producing lack of fusion at wider weld gaps. For a given electrode size, optimum travel speeds and amperage ranges must be determined if weld joint root opening tolerances are to be successfully determined. The lower travel speed limit is reached when

either: 1) the weld puddle becomes so large that it rolls ahead of the arc and causes lack of fusion at the bottom of the weld bead; or 2) when the weld puddle becomes so hot that it excavates the sidewalls causing excessive undercut. An example of lack of fusion at the bottom of the bead, and undercut caused by slow travel speed is shown in 'Figure 7. Undercut is most often caused by the voltage being too high. Figure 7 shows how undercut leads to lack of fusion.

Figure 7. Undercut that causes lack of fusion

USEABILITY

One of the primary objectives of this study was to evaluate the useability of the twist wire process. Useability is defined as the ability to reliably produce high quality welds, with desired mechanical properties, over a wide range of gap widths, using a wide range of welding parameters even when the joint contains gouges or other local defects.

Because -of the configuration of narrow gap joints, repair of weld defects such as lack of fusion, undercut or porosity during welding is difficult due to the limited accessibility. Also, the repair may cause damage to the side

wall of the joint which will in turn lead to more defects during subsequent welding. Because of this accessibility problem, repairs during welding may eliminate the cost advantage of this process if they happen too frequently.

The useability must also be based on the ability of the final weldment to pass nondestructive testing with a low reject rate. As with other narrow gap welding methods, the biggest hurdles are lack of sidewall fusion, reasonable production weld joint fitup tolerances and weld parameter tolerances. Many previous narrow gap welding methods have failed to be useable because lack of sidewall fusion is obtained when: 1) tight weld joint fitup tolerances can not be met in production; 2) the welding parameter range is too restrictive to be realistically maintained; 3) the parameters must be changed during welding to allow for fluctuations in joint fitup; or 4) seam tracking tolerance requirements are too restrictive and cannot be met.

To evaluate useability, test plates as shown in Figure 8 were run at different amperage, voltage, travel speed, and stickout. The parameters were varied to determine allowable ranges for making sound welds (i.e., good sidewall, fusion, no centerline cracking, no undercut, and very little spatter). A summary of defect types and causes are shown in Table 1.

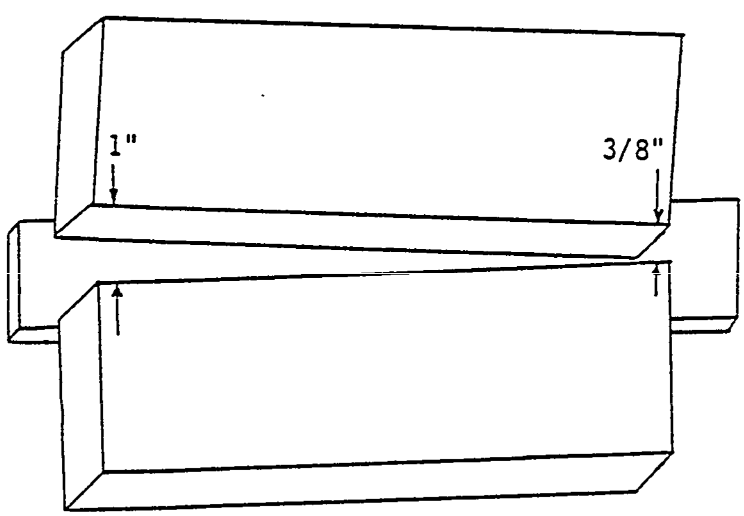


Figure 8. Schematic drawing of weld test plate.

Defect Type	Causes				
	Gap Width	Travel Speed	Amperage	Voltage	Stickout
SOLIDIFICATION CRACKING (Depth/ width >0.80)	too narrow (a)	too fast	too high		
LACK OF SIDEWALL FUSION at bottom of bead	too wide (b)	too fast			
LACK OF FUSION BETWEEN TWO WELD BEADS caused by an excessively large weld puddle rolling in front of the arc	too narrow	too fast	too high		
UNDERCUT (causing lack of fusion on the next pass)	too narrow	too slow		too high	
EXCESSIVE SPATTER, unstable arc			too low	too low	too short

(a) The depth-to-width ratio is labeled D/W on Charts I-IV. Freedom from solidification cracking was assured by D/W < 0.8. Charts I-IV show that D/W increases as the gap width G decreases, therefore D/W = 0.8 determines the <u>minimum</u> reliable gap width.

(b) The "lack of sidewall fusion at bottom of bead" factor is labeled W -G on Charts I-IV. Freedom from lack of sidewall fusion at bottom of bead was assured by W_1-G > 2/64". Charts I-IV show that W -G decreases as the gap width G increases, therefore WI-G = 2/64" determines the <u>maximum</u> reliable gap width

TABLE 1. Summary of defect types and causes

The results of useability tests with various electrode sizes (2x.049", 2x1/16", 2x2mm, 2x3/32") and electrode types (solid, and flux cored) are shown in Charts I through IV. Photographs of macro-etched bead cross sections using the various electrodes and parameters are included in Appendix 2.

D/W vs G (probability of solidification cracking versus gap width) and W_1-G vs G (sidewall penetration in the critical location versus gap width) were

chosen for comparison on each Chart I-IV because these factors will indicate the fitup tolerances. The chances of centerline cracking at narrow groove widths and probability of lack of fusion at wide groove widths define the total acceptable gap width range. For the sake of comparison a travel speed of 10 ipm was used in Charts I-IV. A travel speed of 10 ipm was within the optimum range *for* all electrodes tested. The voltages varied to correspond to the amperage ranges tested. The stickouts varied according to the optimum arc charateristics for each wire tested.

EQUIPMENT

Wire Twister

A machine capable *of* twisting weld quality electrode is essential for evaluating the twist wire welding process. The development of a successful wire twister has allowed the twisting of various sizes and types of electrode with major gains in the area of the flux cored twist wire development, and knowledge of the potential problems with wire quality.

Photo 1 shows the first wire twisting machine developed at Puget Sound Naval Shipyard. From this machine we learned that the twist wire must have the following properties to obtain quality welds:

a) *25 - 30* degree *twist* angle
b) wires must be twisted tightly together
c) wires must not be serrated or gouged
d) wires must be equally twisted around each other
e) must not have residual torque after it is spooled
f) must be properly level wound
g) must be straight

The second prototype wire twister shown in Photo 2 was developed with an emphasis on eliminating electrode helix. Normally, after the wire is twisted it is at residual yield point torsion. When the wire at yield point torsion is bent over the curved surfaces of the drive wheels or the wire take up spool it exceeds the yield point and is plastically eformed into a permanent helix.

The .045" diameter twist wire with helix will weave from side to side in the joint during welding causing lack of fusion when the wire wanders too far from the centerline of the joint. A wire straightener will not eliminate the helix problem with .045" diameter electrode since the wire is so flexible it can not be easily plastically straightened. However a wire straightener is effective on the larger diameter wires. Therefore, helix on larger diameter wire (2mm, 3/32") is not critical to the welding process.

The second wire twister eliminated helix by backspinning the take-up spool end of the wire so that it rotates in the grooves of the drive wheel. In this way the torque is relieved at the same time the wire is bent over the surface of the drive wheels. When the torque is lowered below the yield point, the added bending force over the drive wheels will not result in excessive plastic flow and a helix. For backspinning to be effective, the drive wheels must be large enough to transmit torque over the curved surface. The wire must be free to turn axially.

The backspinning also eliminates the residual torque in the as-spooled wire. Residual torque in the spooled wire produces a strong tendency for the wire to spring off the spool and tangle. Too much backspinning will cause reverse helix and may cause the wire to untwist. If the wire untwists a larger composite wire diameter is created which causes the wire to hang up in the contact tip resulting in an erratic arc and burn back.

The tension equalizer shown in Photo 3 attached to the end of the spinning arbor is an important part of the wire twisting machine. This device equalizes the feed rate of the two wires as they leave the arbor and are intertwisted.

Without the tension equalizer, a small differential change in the tension of the wires will cause them to twist unequally around each other. This

unequal twisting or looping, even when difficult to detect visually, will cause the electrode to hang up in the contact tip due to the increase in the combined twist wire diameter.

The tension equalizer shown in Photo 3 is made up of four wheels keyed together. When one wire is pulled from the arbor, torque is transferred to the other wheels. This forces the second wire to feed at the same rate, producing equal twisting.

Welding Equipment

The gas shielding device and the welding torch must be designed specifically for narrow gap twist wire welding. The remaining equipment is similar to conventional Gas Metal Arc Welding (GMAW) or Submerged Arc Welding (SAW) equipment. Currently, the only twist wire welding equipment available on the market is the TW-1 system made by Kobe Steel, the pioneer of twist wire welding. The TW-1 system is a well designed, complete equipment package that was made specifically for twist wire welding. A complete list of system components is included in Appendix 1.

Two special features of the TW-1 are a remote control adjustment for centering the electrode and an excellent shielding gas system. The centering device is a small remote hand held pendant on a four foot cable with two buttons to move the electrode left or right to center the electrode in the gap. Currently, the travel speed can not be adjusted during welding because a small turn of the knob will set the travel speed beyond the acceptable range. It would be beneficial to have a fine travel speed adjustment knob which could be turned at least 90 degrees to vary the travel speed smoothly within an acceptable range of set travel speed limits. The TW-1 shielding system is made up of two separate, interchangeable devices for different base metal thicknesses. For joint depths 2" to 11" a shielding gas nozzle is

attached to the torch so that the shielding gas ports are inside the groove. For weld passes 2" deep up to the cover pass the shielding *gas* nozzle is replaced by a shielding gas box which forces and floods shielding gas into the joint from above the plate surface.

CONCLUSIONS

Presently, Puget Sound Naval Shipyard's testing of the twist wire process has focused on detenining which types and sizes of twist wire are useable for narrow gap welding. The conclusions, based on the Charts I-IV, are summarized below:

a) 2x1/16" solid twist wire is unacceptable. The D/W ratio versus G curves of Chart I are too high and intersect the D/W=0.8 limit at a high gap width value. The sidewall penetration in the critical location WI-G versus gap width G curves of Chart I are low, thus intersecting the W_1-G=1/32" limit at a low value of G. Thus, the minimum gap width is too wide, the maximum gap width is too narrow, and the gap width range is not broad enough to allow for the fitup tolerances required in the shipbuilding industry. The useable gap width range is marginally acceptable at 425A;
however, the current density is too low at 425A for reliable *arc* stability.

b) 2x2mm solid twist wire provides a sufficiently broad gap width range between 500A and 550A. The D/W ratio is lowest at 500A, thus the gap width can be narrower and still avoid solidification cracking. Below 500A the arc becomes unstable. Above 550A the D/W ratio is too high to reliably produce a crack free weld pass over a sufficiently wide gap width range.

c) 2x1/16" flux cored twist wire is unacceptable. The sidewall penetration curves of Chart III are too low and intersect the WI-G=1/32" limit at a low gap width value. Thus the range of usable gap widths is not broad enough to allow the required +1/8" fitup tolerance believed to be necessary in

the shipbuilding industry. The D/W ratio versus gap width curve is acceptable over a broad amperage range of 350A to 550A. The low D/W ratios are typical of flux cored twist wire with arc stabilizers producting continuous arc rotation.

d) 2x3/32" flux cored twist wire has an' extremely wide range of useable gap widths, very high sidewall penetration curves, extremely low D/W ratio curves and a broad amperage range.

As a practical matter, the ideal joint width range is 1/2" - 3/4". Below 1/2" joint accessibility and visibility become more of a problem. Defects which occur in a groove less than 1/2" wide are more difficult to remove than defects in grooves with wider gaps.

Table 2 below shows the values for D/W and W_1-G at 1/8" intervals within the desireable gap width range of 1/2"-3/4".

		G range		D/W (0.8 max)			W_1-G (.03 min)		
	Amperage	min.	max.	G= 1/2"	G= 5/8"	G= 3/4"	G= 1/2"	G= 5/8"	G= 3/4"
2x2mm solid	500	.47	.83	.78	.63	.53	.07	.05	.04
	550	.56	.83	.88*	.75	.60	.07	.05	.04
	650	.68	.83	.97*	.85*	.74	.10	.08	.06
2x3/32" flux cored	550	.37	.86	.60	.48	.38	.14	.07	.03
	650	.37	1.	.62	.56	.50	.19	.15	.13

* D/W is unacceptable (see footnote a of Table 1).

Table 2. Comparison of the two useable twist wire electrodes

At this time in the test program it is known that the 2x2mm solid twist *wire is* suitable for production use and it appears that the 2x3/32" flux cored twist wire has additional advantages over the solid twist wire for narrow gap welding in the shipbuilding industry. It is important to note that much additional testing is required to determine the useability. Additional

useability tests should include tests to determine:

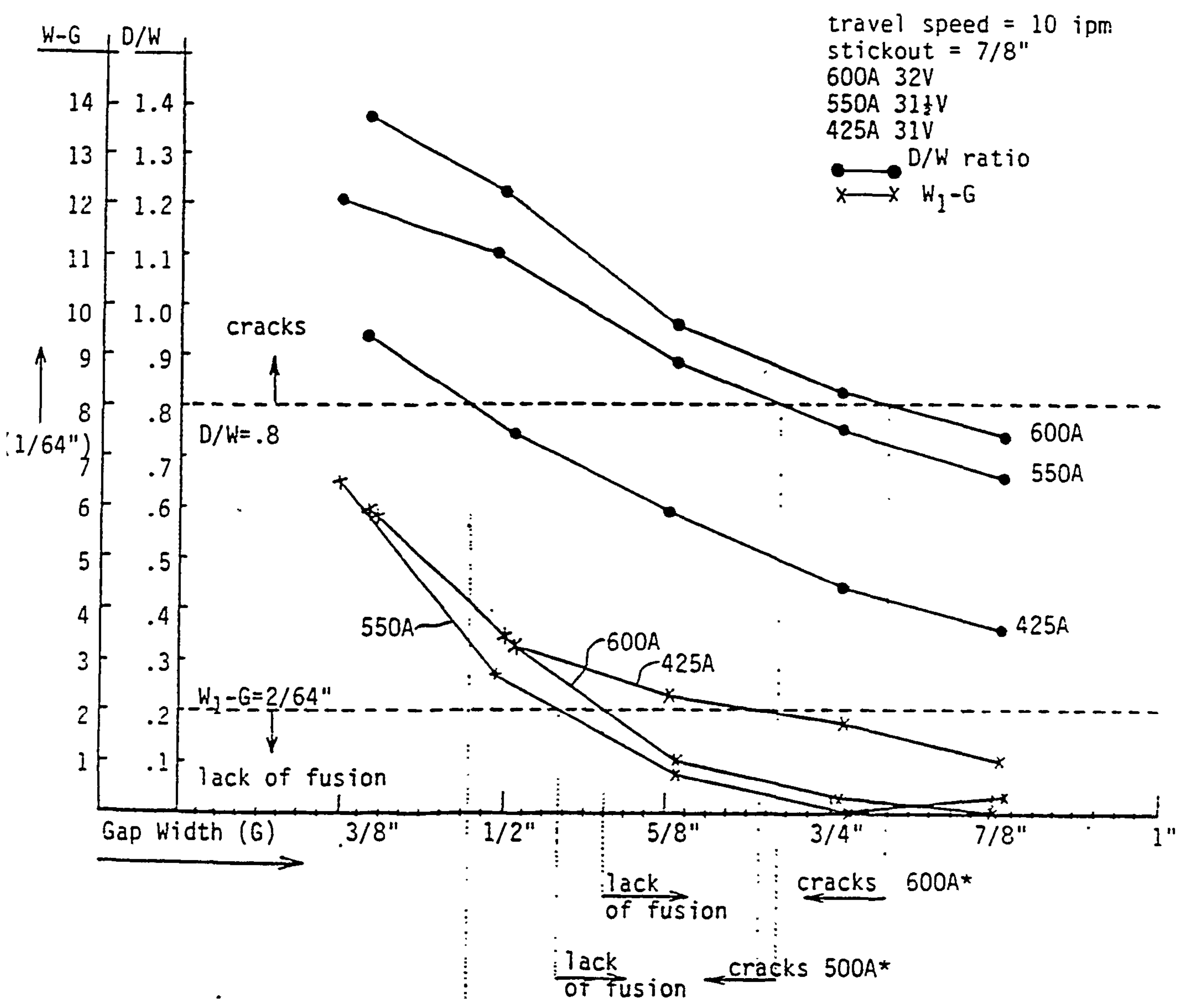
1) the electrode centering tolerance
2) the travel speed range
3) acceptable amperage, voltage, and travel speed combinations
4) contact tip life
5) sensitivity to defects in the sidewall
6) ability to repair surface defects by carbon arcing and grinding

LIST OF REFERENCES

1) Kimura, S., Ichihara, I., and Nagai, Y., "Narrow-Gap, Gas Metal Arc Welding Process in Flat Position", Welding Journal, July 1979, pages 44-52.

2) Yasuhiro, Nagai, Chigasaki; T. Osisada, Kashinura, Kamakura; Kunio, Kaita, Kamakura, & Tetsuro Kawaberi, Kamakura, all Japan; assigners to Kabushiki Kaisha Kobe Seiko Sho, Kobe, Japan; "Arc Welding Process Using a Consumable Stranded Wire Electrode ", United States Patent Publication No. 4,386,259, filed March 31, 1981.

2 X 1/16" SOLID ELECTRODE



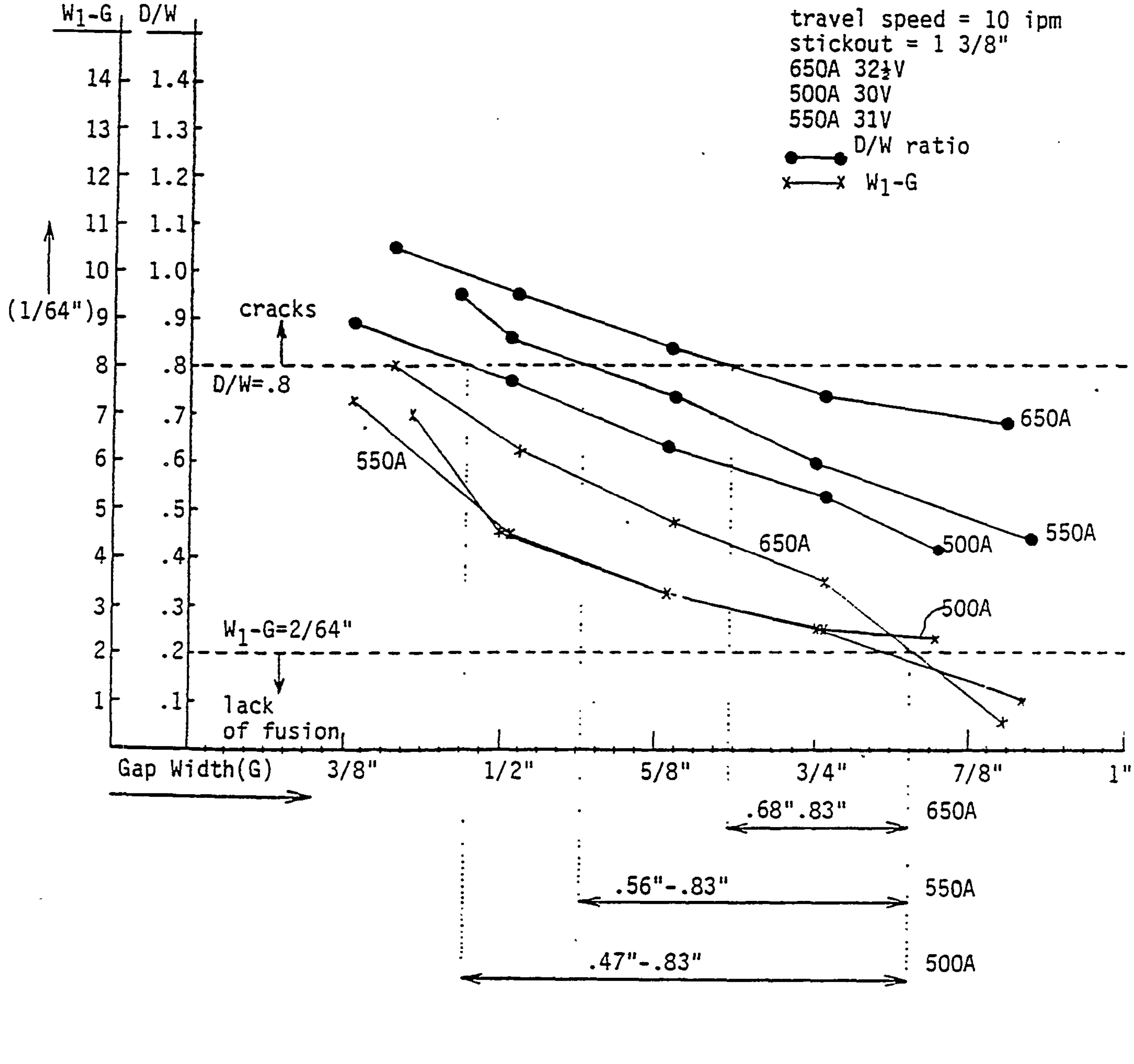
Cracks useabl range lack
47" -70" - of fusion 425A

* No useable range at high amperage because of a high risk of cracks or lack of fusion at any value of G.

See footnotes a&b of Table 1.

Chart I

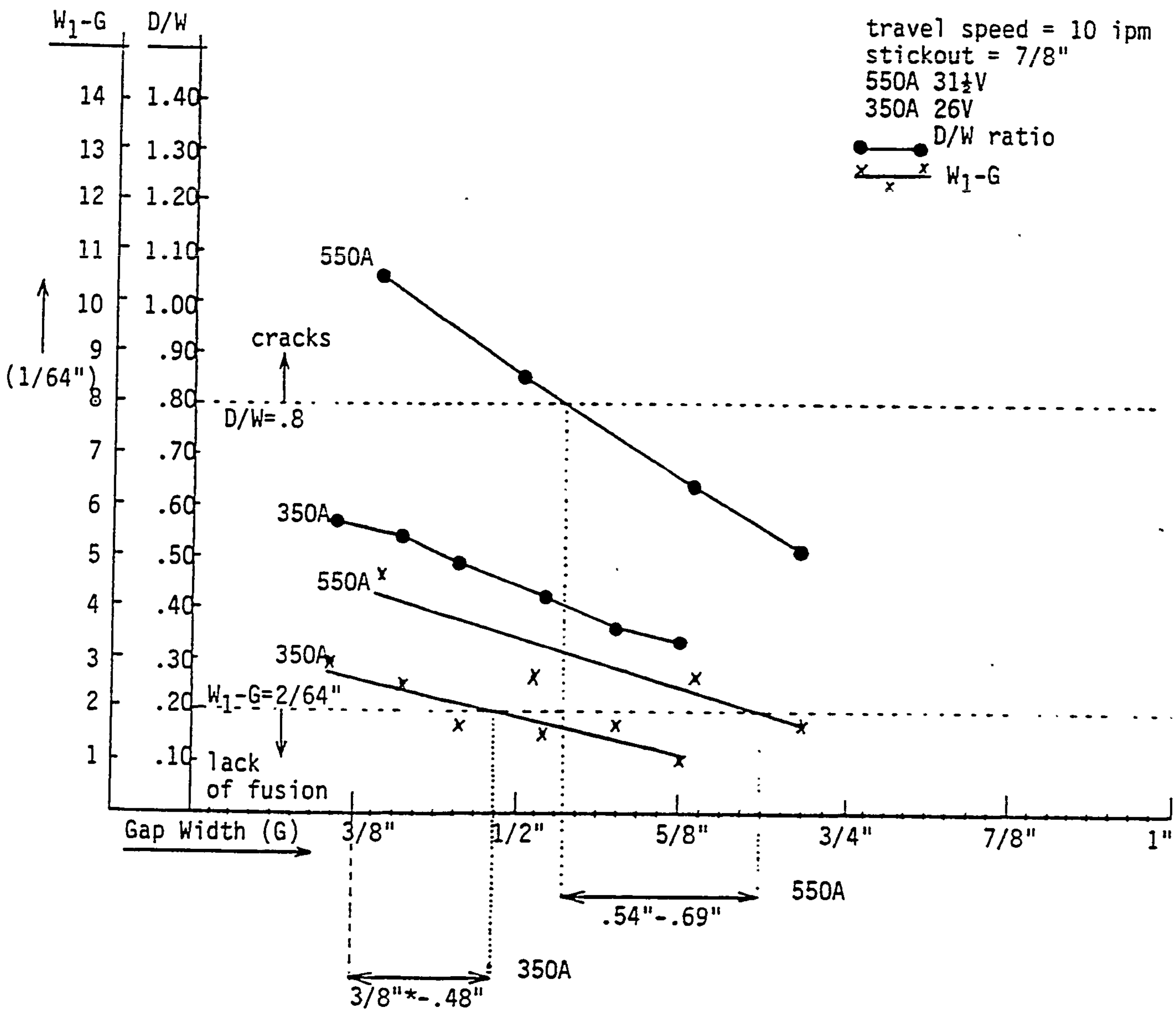
2 x 2mm SOLID ELECTRODE



See footnotes a&b of Table 1.

Chart II

2 x 1/16" FLUX CORED ELECTRODE

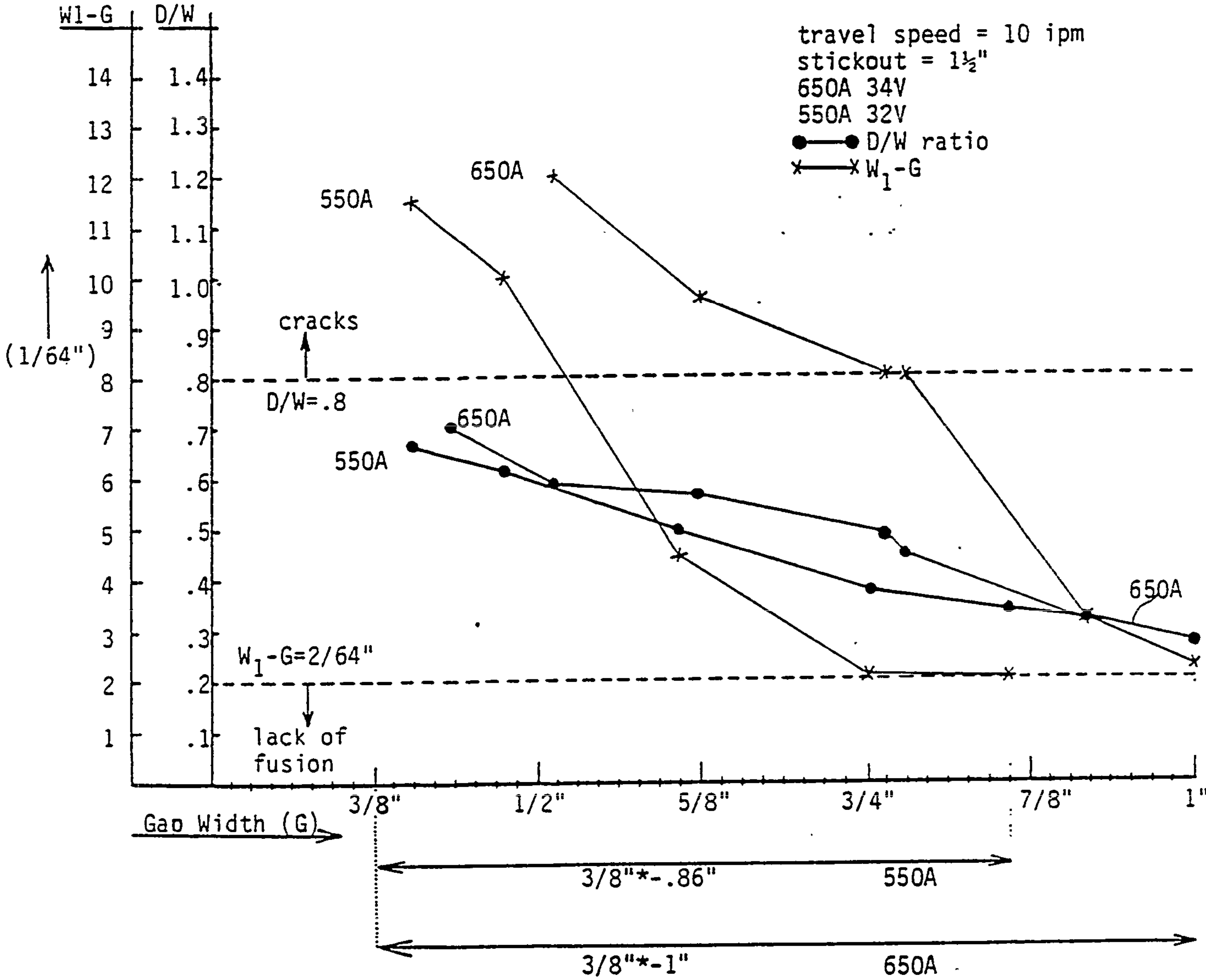


See footnotes a&b of Table 1.

* The D/W ratio is so low with flux cored wires that the D/W ratio curves only intersect the D/W=0.8 limit at high amperage. At low Amperage the lower gap width limit is set at 3/8". Below 3/8" the gap width is too narrow to accomodate the contact tip.

Chart III

2 x 3/32" FLUX CORED ELECTRODE



See footnote b of Table 1 for explanation of upper limit.

* The D/W ratio is so low with flux cored wires that the D/W ratio curves do not intersect the D/W=.8 limit. The lower limit is set at 3/8". Below 3/8" the gap width is too narrow to accomodate the contact tip.

Chart IV

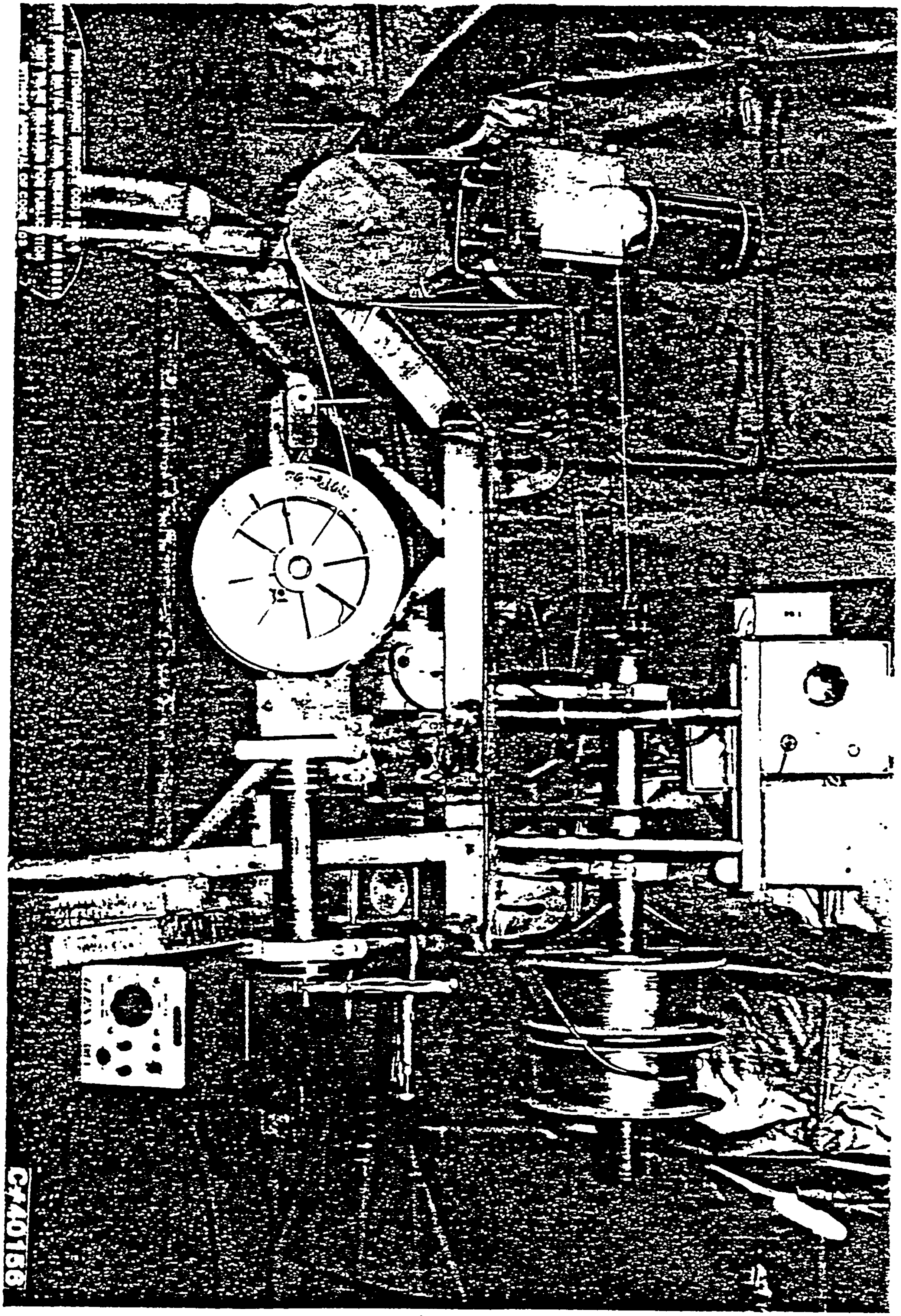


Photo 1

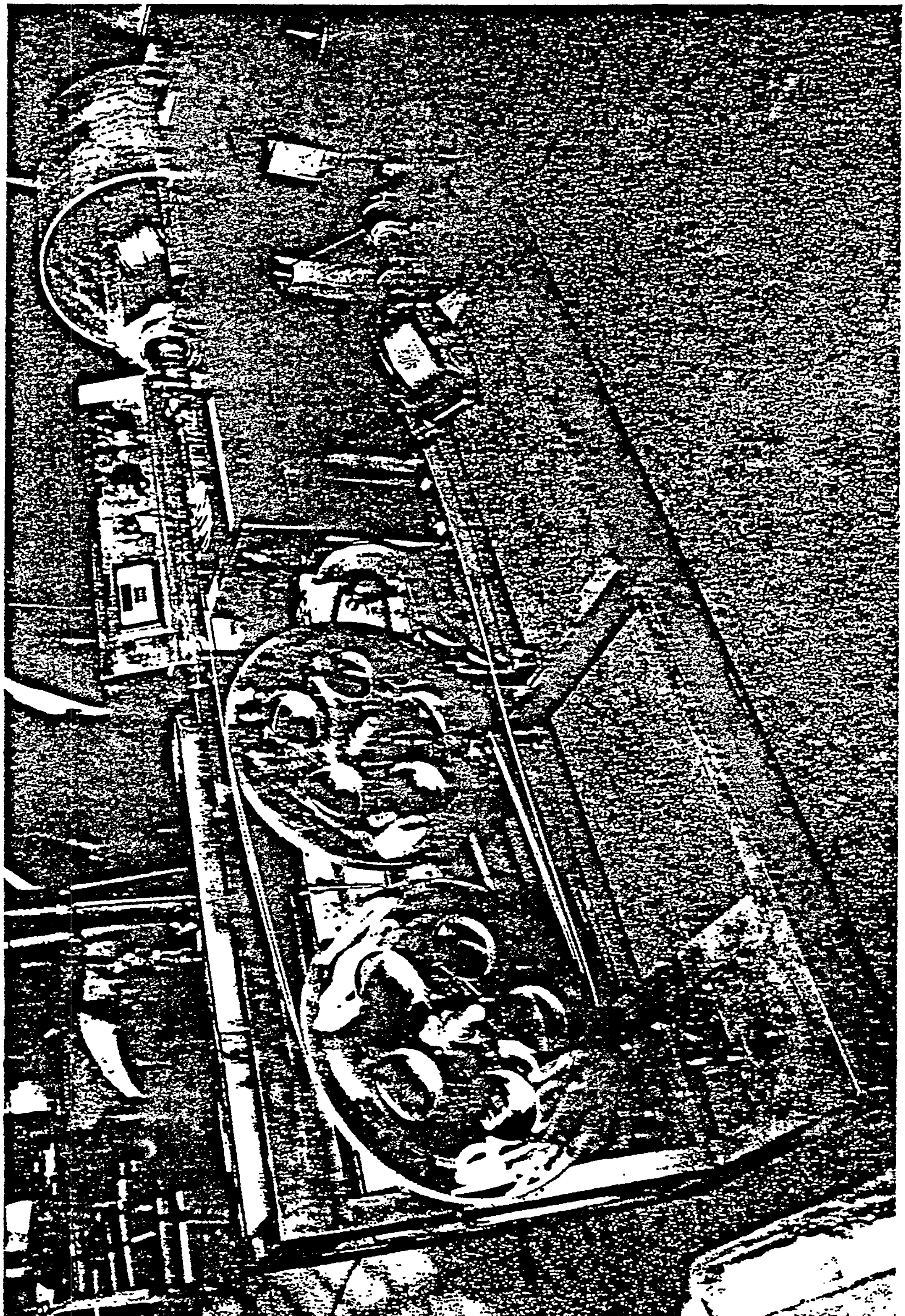


Photo 2

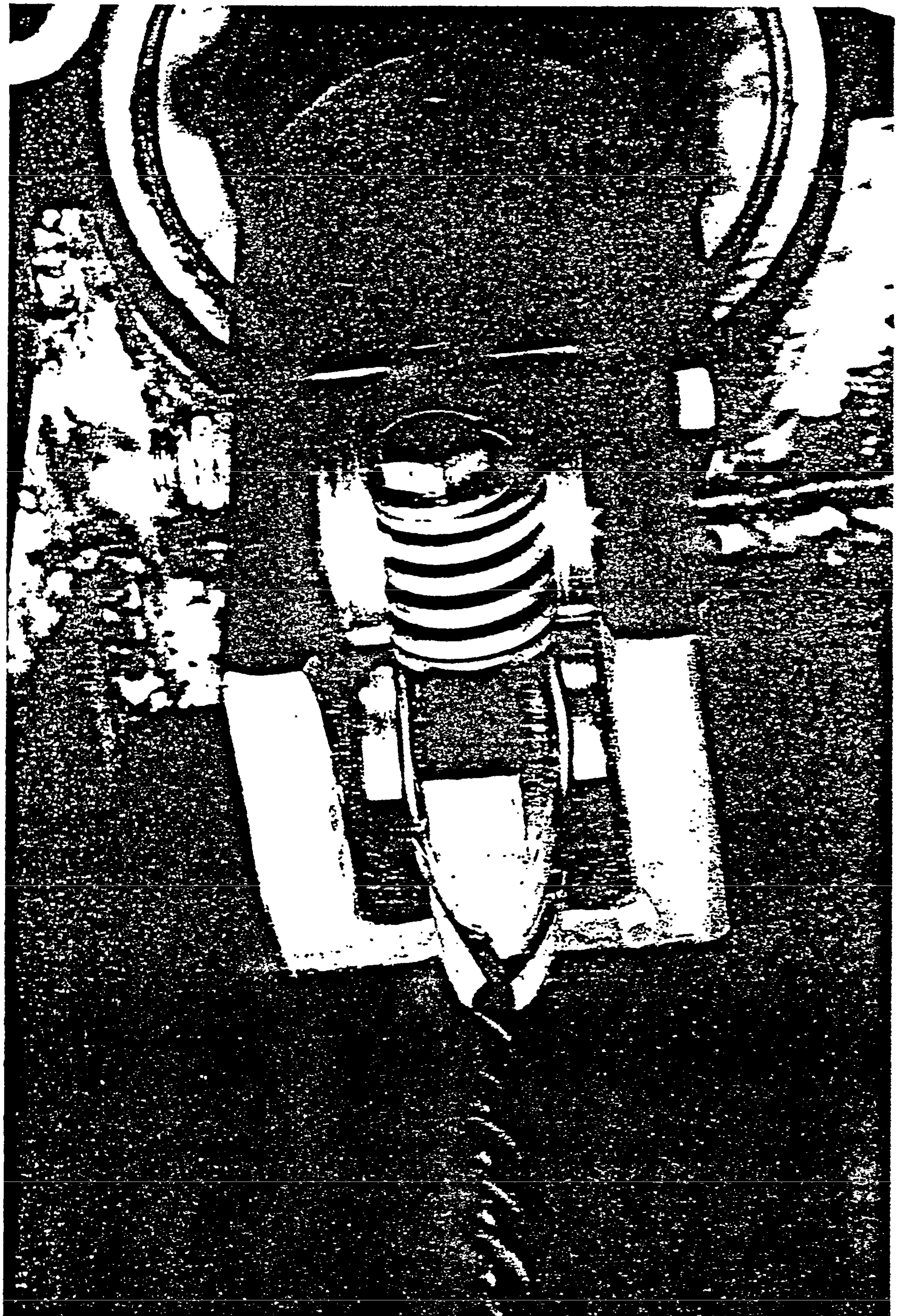
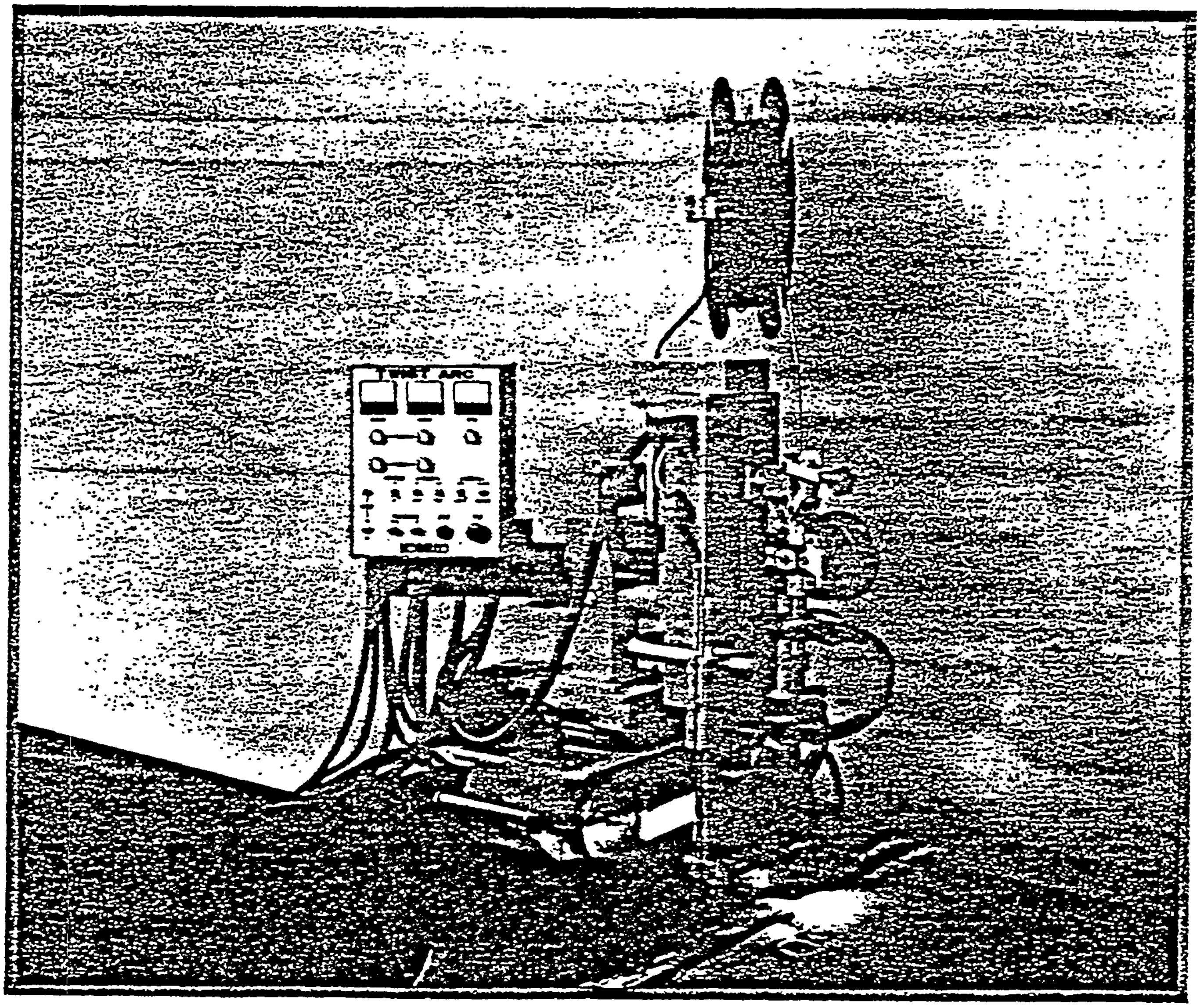


photo 3

TW-1

TWIST ARC WELDING EQUIPMENT

Narrow Gap Gas Shield Arc Welding Equipment



KOBELCO

KOBE STEEL, LTD.
WELDING DIVISION

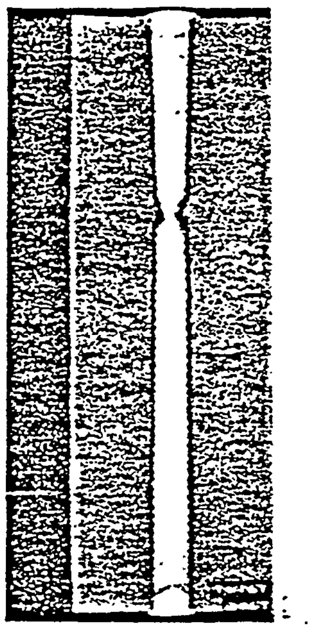
TW-1

TWIST ARC Welding Equipment "T W - 1 " demonstrates the best reliability and economy in the TWIST ARC welding process.

Features

o Easy operating welding equipment because of its simples structure.

For conventional narrow gap welding equipment. it is necessary to bend the wire and to have oscillation in order to penetrate a narrow gap wall. But, with this equipment using a special wire of two threaded wires. such a function is not required and by simply feeding the wire into the center of the narrow gap, narrow gap welding can be performed at a high reliability.



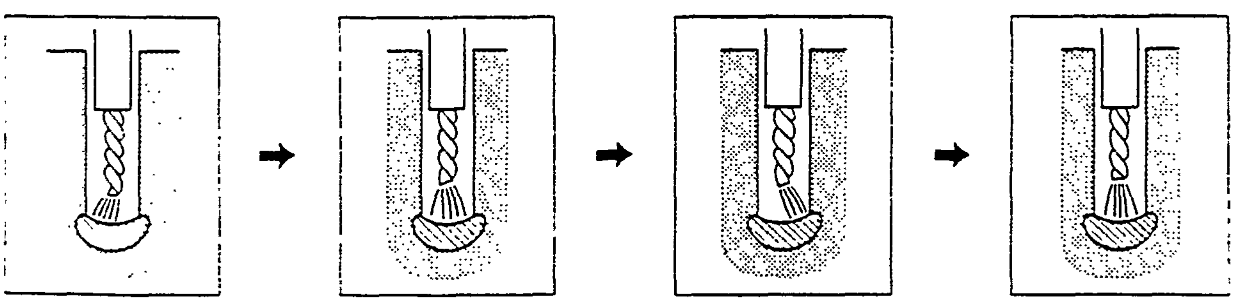
G Up to 300mm thick welding is available because the location of the long stroke torch can be adjusted up and down.

c Torch location can easily be adjusted in the narrow gap with just observing the are by a remote pendant box which can be held in one hand.

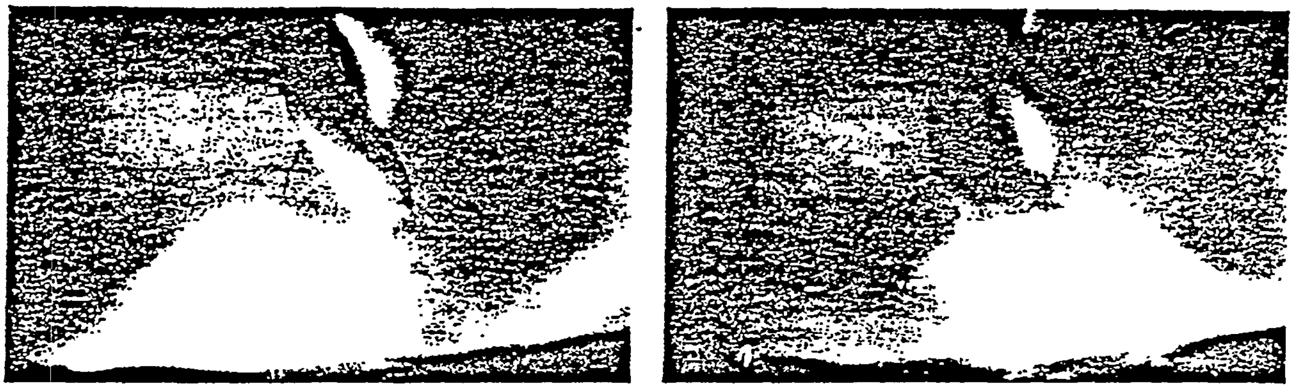
.f Being removable from the travel carriage. the welding head of TW-1 can be easily mounted on the manipulator.

TWIST ARC Welding Method means

This IS a method which naturally causes swing and rotation movement of the welding arc generated from the ends of two intertwined wires. this assuring sufficient penetration into the narrow gap wall. assurmg attainment of concaved bead surface shape and preventing blow holes inherently occuring in MIG welding. because of the effects of active convection and mixture of molten metal characteristic of the above-mentioned movement.



Swing and rotation of welding arc



Generating status of welding are
(as show by htgh-speed film)

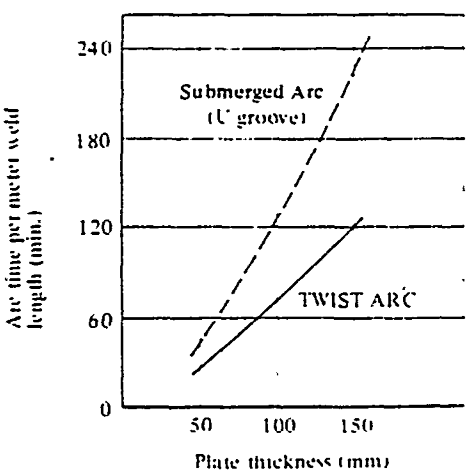
Features of the TWIST ARC Welding Method

- Highly Efficient and Economical

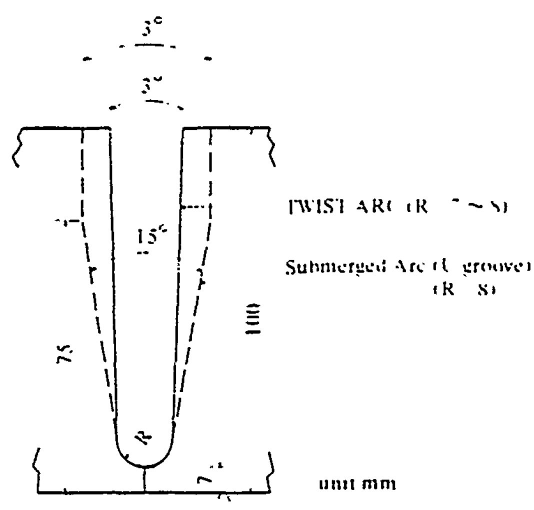
Because the cross-section of a gap welded by the TWIST ARC is smaller than that welded by Sub-merged Arc, this method is economical as well as highly efficient.

- High Reilability with : Simple Operation

Because of the above mentioned features of TWIST wire, sufficient penetration into the narrow gap wall easily be obtained, and by roughly adjusting the wire feeded point to the center of the narrow gap, highly reliable welding can be performed.



A comparison of welding arc time



An example of narrow gap shape

Appendix 1

Application

- Applicable position : Flat position
- Applicable plate thickness : Max. 300 mm
- o Applicable material : Mild steel - 80 kg/mm' class high tensile steel, low-alloy steel for boiler and pressure vessel application
- o Groove width : 14^{+4}_{-2} π mm (I, J and U form)
- o Applicable joints : Circumferential and longitudinal butt joints for boiler and pressure vessel.

  Butt joints of thick plate for hydraulic power generator. heavy machinery. etc.

Typical Welding Conditions

- Welding current : 500 ~ 550A
- Welding voltage : 29 ~ 32V
- Welding speed : 20 ~ 40 cm/min.
- Shield gas : 80% Ar + 20% CO_2

  For shield gas nozzle

  Primary gas 5 ~ 10 min

  Secondary gas 50 . min

  For shield gas box

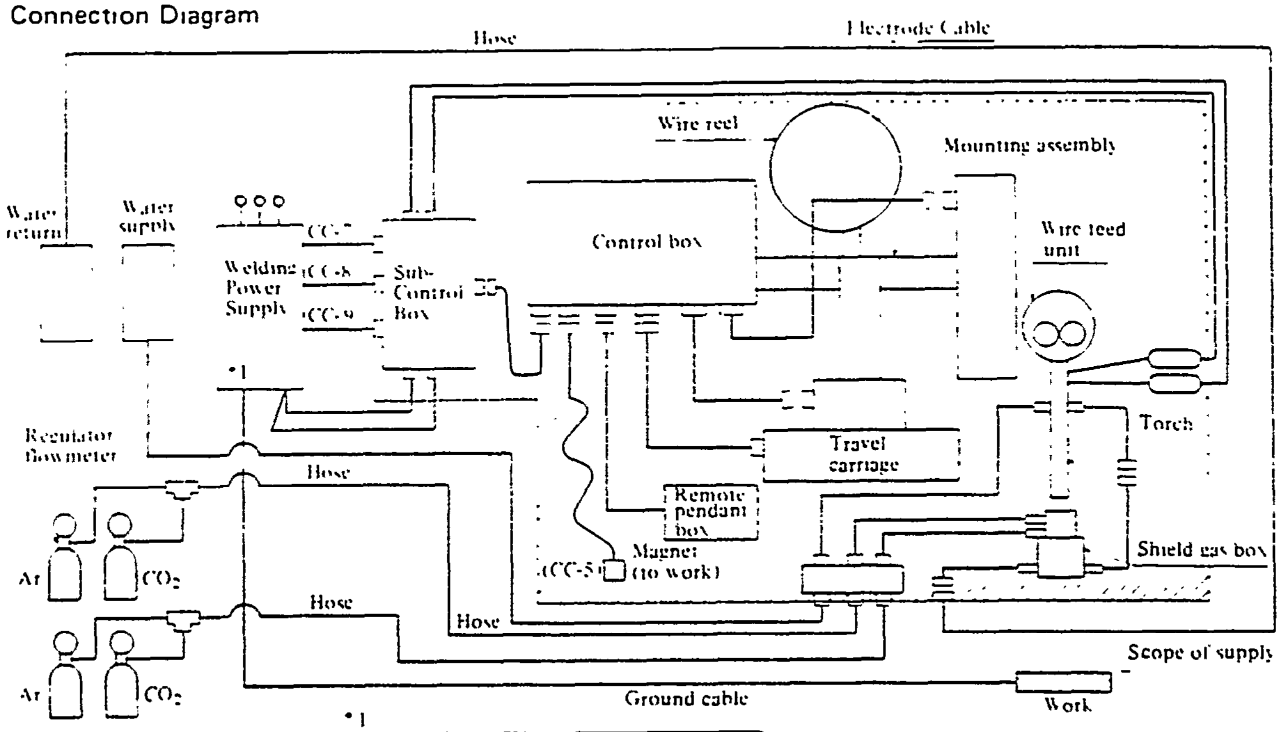
  Primary gas 50 ~ 60 . min

  Secondary gas 50 ~ 60 ./min.

Components and Specifications

Components		Specifications
Travel Carriage	Travelling. method	Rail guide friction method
	Travel speed	I .S - 85 cm/mm. 15.9 - 33.5 mch/min).
	Clutch	A manual clutch
	Dimensions and weight	330W x 760D x 17SH mm 39Kgt (13.OW.x 29.9D x 6.9H inch, 86 lbs)
Mounting Assembly)	i Cross-steam adjustment	Stroke: 80mm (3.2 inch) electric tnching method Slide speed: 12/14 cm/min. (4.7/5.5 inch/min) (50/60 Hz)
	Vertical Head adjustment	Stroke: 350mm (I 3.8 inch) electric inching method Slide speed: 24/28 cm/mm. 19.4/II inch/min.) (50/60 HZ)
	Torch angle adjustment	±110°(to the level) by manual hand knob
	Dimenstons and weight	57OW x 300D x 7OOH mm. 75Kgt (22.4W x II 8D x 27.6H Inch. 165 lbs)
Wire Feed Unit	Wire feed speed	Max 6 m/min it 9.7 it/min.)
	Applicabel wire size	2.0 x 2.0 mm (0.079 x 0.079 Inch)
	Dimensions and weight	26OW x 280D x 500H mm. 10kgf (10.2wx11.odx 19 .7H inch 22 lbs)
Shield Gas Box and Vertical slide	Shield gas box	Dual shilding. water cooled type
	Vertical slide	by manual hand knob
	Weight	6 kgf (13.2lbs)
Shield Gas Nozzle	Shield gas nozzle	Dual Shielding. water cooled type
	Weight	4 kgf (8.8 lbs)
Torch	Applicable wire size	2.0 x 2.0 mm (0.079 x 0.079 o Inch)
	Weight	2 Kgf (4.4lbs)
Tip	Applicable wire size	2.0 r 2.00 mm (0.079.007 inch)
Wire Reel	Applicable wire weight	20 kgf (44lbs)
	Dimensions and weight	500φ x 240D mm 9 Kgt (19.7φ x 9.4D inch, 19.8 lbs)
Control Box	Controlling items	° Weld start ° Weld stop ° Welding current rheostat (with meter) ° Welding voltage rheostat (with meter) ° Travel speed rheostat (with meter) ° Gas test ° Wire inching (up/down) ° Cross-steam adjustment inching ° Vertical head adjustment inching ° Travel (forward/backward) ° Travel (automatic/manual) ° Crater current rheostat ° Crater Voltage rheostat
	Dimensions and weight	310W x 220D x 520H mm. 28 Kgt (12.2W x 8.7D x 20.5H inch, 61.7 lbs)
Remote Pendant Box	Controlling item	Cross-seam adjustment inching
Cables	Control cable	Welding power supply-Control box 20 m (65.6 ft)
	Electrode cables	80 mm² x 1 m x 2 pcs (with cable connectors) (0.12 inch², x 4.3 ft)
	Arc voltage detection cable	10 m (with a permanent magnet) (32.8 ft)
Sub-control Box\	Controlling items	Control power source ON/OFF Control power source indication lamp
	Dimensions and weight	300W x 400D x 210H mm. 20Kgt (11.8W x 15.7D x 8.3H inch, 44 lbs)
	Note: Characteristic of D.C welding power supply and specification of output control rheostat should be noticed in advance	
Rull	Dimensions and weight	250W x 1,800L x 60H mm. 30 Kgt (9.8W x 70.9L x 2.4H inch, 66 lbs)

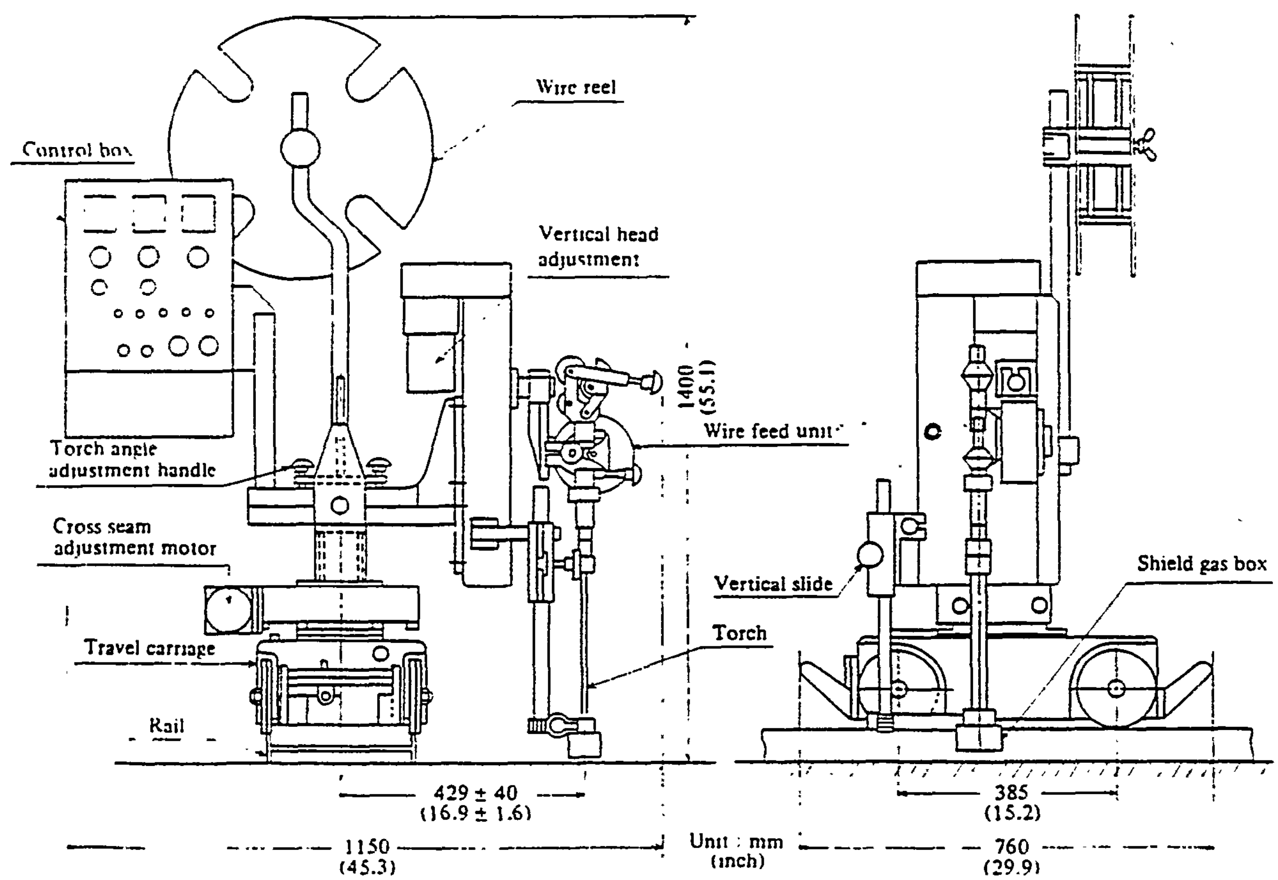
Connection Diagram



*1

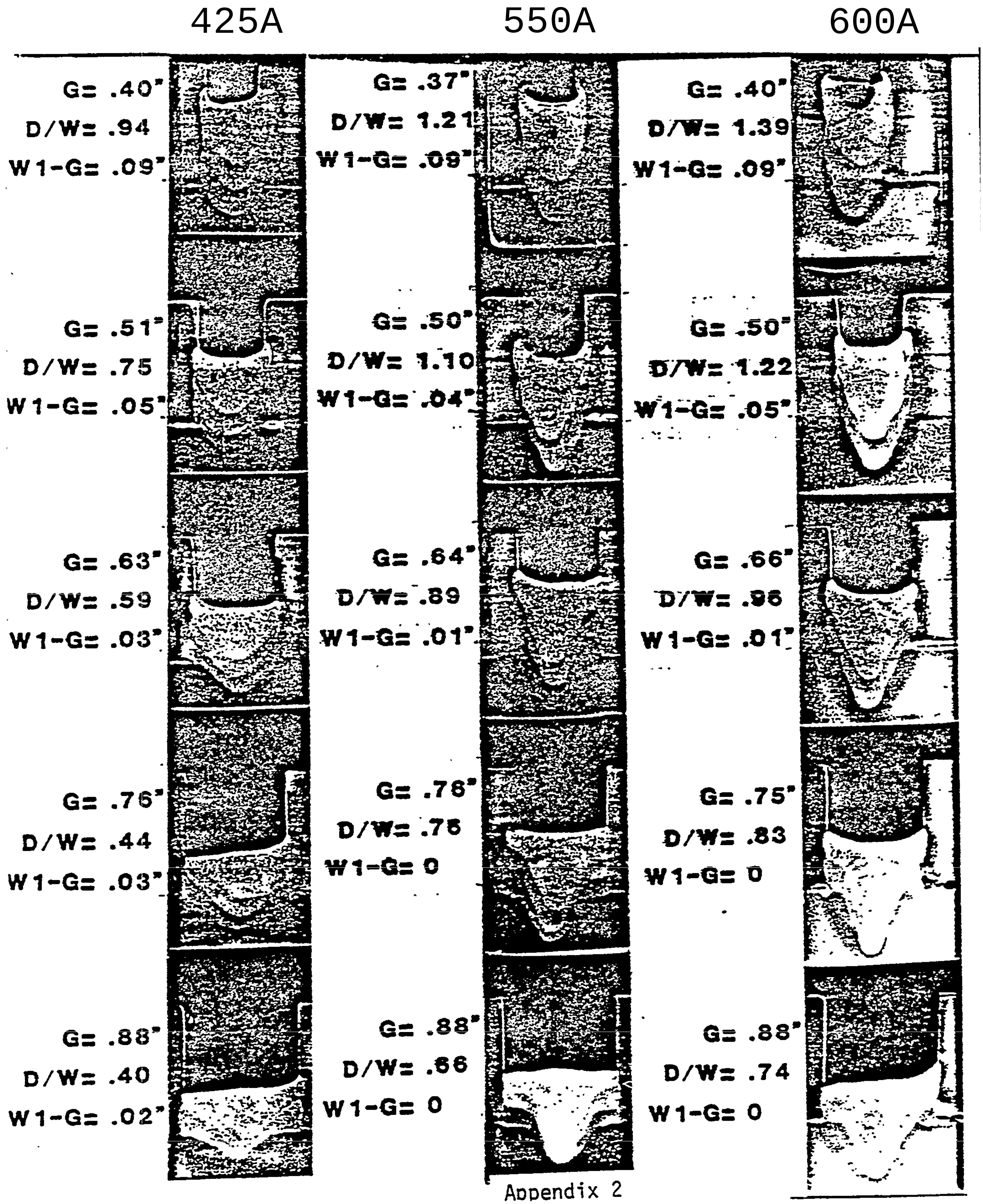
	Specification
Type	SCR output controlled three phase D.C. power supply
Characteristic	Dropping/constant voltage Characteristic should be noticed in advance.
Capability	Above 550 Amperes 34 Volts 100% duty cycle

General Drawing



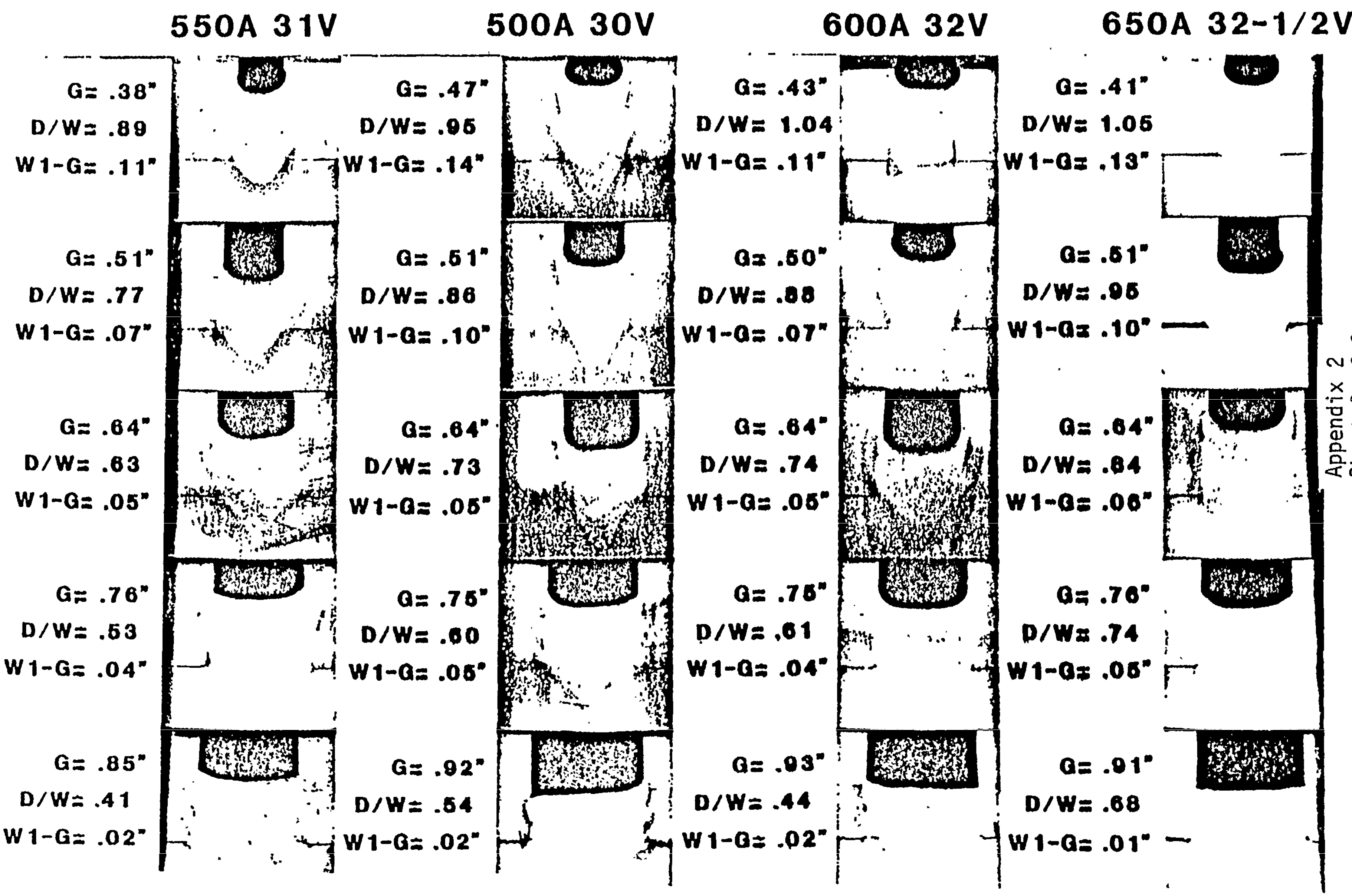
Appendix 1
Sheet 6 of 6

Twisted l/16" Diameter Solid Wire Electrode

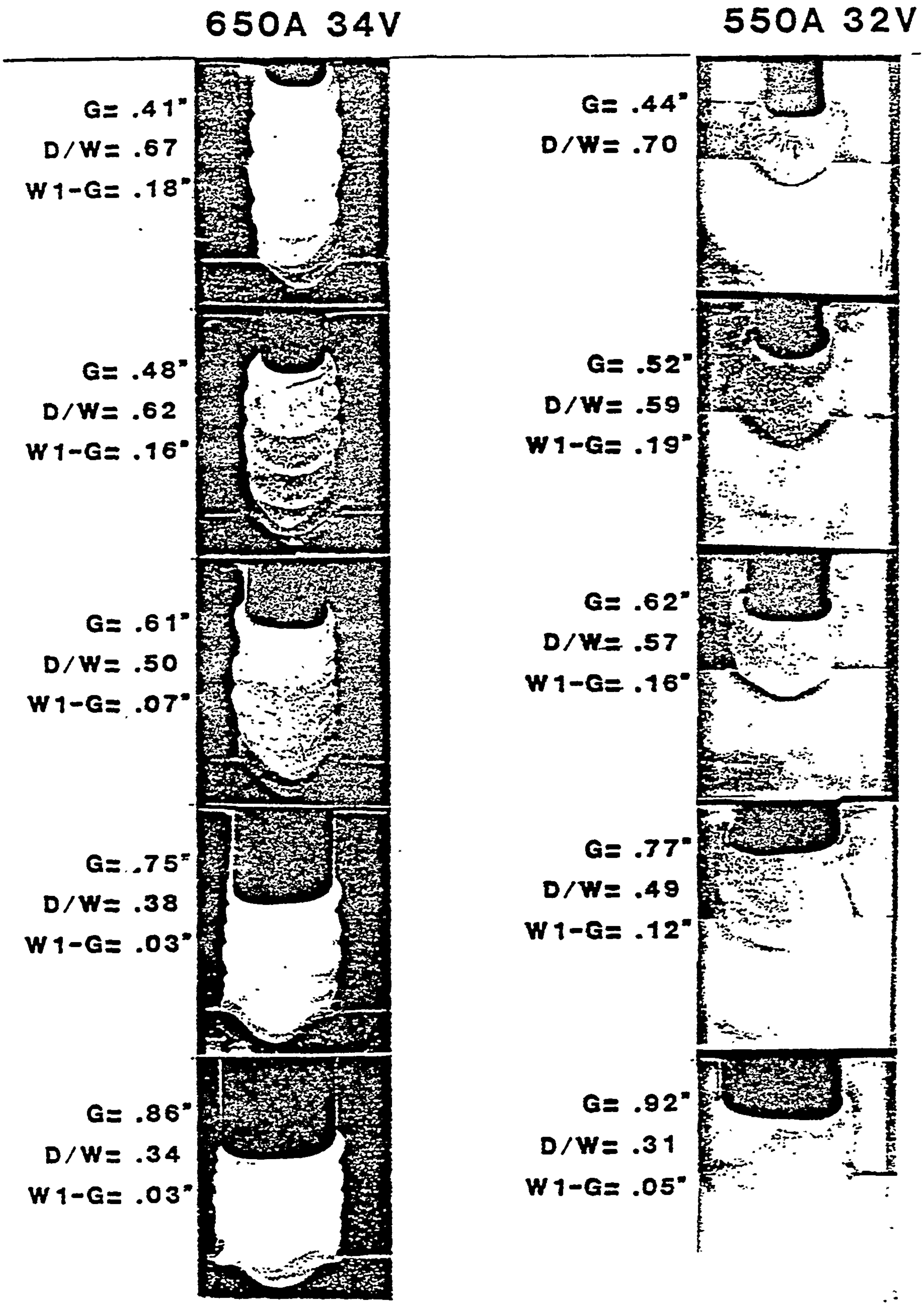


Appendix 2
Sheet 1 of 3

Twisted 2mm Diameter Solid Electrode



Twisted 3/32” Diameter Flux Cored Electrode



Appendix 2
Sheet 3 of 3

Additional copies of this report can be obtained from the
National Shipbuilding Research and Documentation Center:

http://www.nsnet.com/docctr/

Documentation Center
The University of Michigan
Transportation Research Institute
Marine Systems Division
2901 Baxter Road
Ann Arbor, MI 48109-2150

Phone: 734-763-2465
Fax: 734-936-1081
E-mail: Doc.Center@umich.edu